A Review of Existing Farmland Intrusion Detection Systems

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ABSTRACT

Several methods for detecting intruders on a farmland be it humans or animals has evolved overtime from traditional to evolving technologies. Some of the traditional methods incorporate structure block walls around the farm, introducing deterrent plants, electric fences or plants that give out displeasing scents while a few of the evolving technologies include but not limited to wireless sensor networks, deep learning algorithms and internet of things. This paper provides a review of existing farmland intruder detection solutions of different authors with focus on methods ranging from electric fences to Wireless Sensor Networks to Internet of Things (IoT).

General Terms

Object detection, deep learning, Computer Vision, Farmland security.

Keywords

Internet of Things (IoT), Farmland Intrusion Detection, Deep Learning, Wireless Sensor Networks, Deep learning.

1. INTRODUCTION

The economy of many nations on the planet is subject to agriculture. Despite the financial development and advancement, farming is the bedrock of the economies around the world. Agriculture adds to the GDP as it is the pillar of many nations. It is hard for a country to get by without agricultural activities, not on the grounds that it is a wellspring of food, but since it is associated with the creation of all fundamental human necessities. There is dependably a tremendous loss of farm yields because of animal intrusion on farmlands, crops are being obliterated and lives of farmers are being lost. Farmland security in Nigeria still poses a major problem, as most farmers are continually confronted with issues of checking robbery and obliteration both from humans and animals the same. Normal arrangements could incorporate structure block walls around the farm, introducing deterrent plants, electric fences or plants that give out displeasing scents [1]. These safety efforts are now and again extravagant to set up and furthermore extremely incapable as intruders can undoubtedly bypass them and take as much harvests as possible without the approval of the farmers, particularly when those fences are worked around dull hole. In the respect of smart agriculture, significant contributions to knowledge can be made by utilizing arising technologies like Internet of Things (IoT). As defined by [2], Internet of Things (IoT) is the network of physical things embedded with electronic circuits, sensors, software, and network connection which enables these things to exchange data from one another. IoT can solve agriculture-based problems and improve the quantity and quality of farm production, and hence making farmlands more intelligent and connected [3]. By combining computer vision technology with IoT, it becomes possible to secure farmlands from theft and destruction both from humans and animals. Computer vision is a field of computer science that deals with how computers can gain high-level knowledge from digital images or videos. It is a combination of image processing and pattern recognition. The output of the Computer Vision process is image understanding. It centers around imitating parts of the complexity of the human vision framework and empowering PCs to recognize and process objects in pictures and videos similarly to humans [4].

Many methodologies that involve animal detection utilizing IoT, wading off animal and sending intrusion alert to farmers have been proposed. A few techniques have likewise been developed to detect and recognize animal and human intrusion on a farmland. This paper presents the reviews of previous research on animal and human detection systems.

2. REVIEW OF FARMLAND INTRUSION DETECTION SYSTEMS

2.1 Farmland Intrusion Detection Systems using Wireless Sensor Network

Muneera et al. [16] researched on Internet of Things based alert system for Wild Animal Infringement, Identification and Diversion. Laser sensor nodes are placed at every corner of the farm for monitoring the border. Intruder information is sent to the base station and activates all the nodes surrounding the animal. Flashers and buzzer based are used to divert animals based on the proximity, time, and location with the help of the sensors on each node. A sleep mode is activated when no signals are received from the sensor nodes. Nodes use Wi-Fi to communicate with each other and the router gateway. Cloud computing is used for process distribution and messages are sent via Message Queue Telemetry Transport (MQTT) protocol which is appropriate for secure and fast communication in villages that require smaller code footprints. A system which detects animal intrusion and diversion by less than 5% was achieved. However, the class of animals used for the scope of the research was not discussed.

Ibam et al. [20] designed and implemented wireless sensor networks for farm monitoring and security. The design of the system is based on wireless sensor networks (WSN) and some of the components used are processor board, intrusion detection sensors, cameras, and buzzer alarms etc. GSM module is utilized for sending SMS to the farmer stating the type of intrusion. A system for detecting intrusion on a farmland was developed. However, the system cannot differentiate between

authorized and unauthorized entry into the farm. Also, there is no image processing module to identify the kind of intruder.

Prajna et al. [19] developed an IoT-based Wild Animal Intrusion Detection System fully intent on providing protection from assults of wild animals and and subsequently limiting losses to farm owners. PIR Sensors detects the animal's movement, and the sensor thus triggers the camera to snap the picture of the animal and transfer the image for processing via microcontroller through Wireless Sensor Networks (WSN). The limitation is that the research only considered two kinds of wild animals and cannot detect human intruder. Also, the object detection model used was not stated.

Varsha et al. [24] proposed a crop protection system to divert animals from the farmland based on wireless sensor networks. The objective of the work was to develop an animal intrusion detection and deterring system, which will be able to sense, report and take preliminary preventive actions in an automated manner. Laser assisted perimeter guarding sensors were mounted at the corners of the farm to detect entry of animals and activate flashers and sound devices to divert the animals based on time, location, and distance. MATLAB was used to develop the Graphical User Interface of the system. An adaptable wireless sensor network-based crop protection system to divert animals from the farm was developed. However, the system cannot differentiate between authorized and unauthorized entry into the farm. Also, there is no image processing module to identify the kind of intruder.

Nagpal and Manojkumar [25] proposed Hardware Implementation for Intruder Recognition in a Farm using Wireless Sensor Network. The objective of the work was to develop a Wireless Sensor Network based system to detect unauthorized entry into the farm. The sensors continuously send information to the Arduino and the arduino checks the signal to detect the presence of a human or an animal. A buzzer is then triggered either to take immediate action or caution the unauthorized entry. The work used Frequency Identification (RFID) tags to exclude movement of authorized persons. A WSN based monitoring system that can detect unauthorized entries of animals and humans into the farm was developed. The work only detects motion and immediately moves on to acting. The kind of intruder was not considered.

Table 1. Farmland Intrusion Detection Systems using Wireless Sensor Networks

Objective	Sensors	Microcontroller	Author	Year
Animal Detection and recognition	Lases Sensors	WSN	Muneera *et al.*	2020
Wild animal detection	PIR Sensor	WSN	Prajna *et al.*	2018
Farm Monitoring and Security	Wireless intrusion detector	ZigBee radio transceiver	Ibam *et al.*	2018
Animal Detection	Laser Sensors	Wireless Sensor Networks	Savagavi *et al.*	2017
Unauthorized entry detection	PIR Sensors	Arduino Micro Controller	Nagpal and Manojkumar	2016

2.2 Farmland Intrusion Detection Systems using Internet of Things (IoT)

Mythili et al. [18] presented IoT Based Smart Farm Monitoring System to reduce human intervention and increase crop cultivation. The methodology is a combination of hardware and software components. The sensors used are temperature sensor, humidity sensor, Passive Infrared Sensor (PIR) and soil moisture sensor. A GSM module is connected to the Arduino microcontroller to facilitate messaging service. At the end of the research, an easy to use, low maintenance cost system was achieved. The work could only detect motion around the PIR sensor and doesn't have knowledge of what is intruding.

Santhiya et al. [22] proposed a smart farmland using raspberry pi for crop protection and animal intrusion detection system. The objective of the research was to develop an animal intrusion detection system using Raspberry pi. Raspberry pi was used to develop the system with three levels for animal diversion. Radio Frequency Identification (RFID) was used to detect the animal that enters the farm. An SMS is sent to the forest officer and the farm stakeholders. An automated system which does not cause any arm to animals during repellent was achieved. Exact location of the intruding animal on the farm is not achieved. Human detection was not considered, and noise pollution was caused by loud irritable noise used to scare off intruders.

Iyapo et al. [21] developed a Motion Detection Alarm and Security System whose objective was to develop close circuit security using PIR sensors and microcontroller for device control. The design consisted of the sensitivity phase, central processing phase and action phase. The study also utilized developmental design to observe the functionality of the device. A motion detection alarm and security system which responds well to the motion sensor when it detects intrusion at the entries was developed. However, the work could only detect motion and could not differentiate between authorized and unauthorized entry.

Ajayi and Olaifa [1] presented intrusion detection in large farmlands and plantations in Nigeria using virtual fences. The objective of the research was to develop an IoT based intrusion detection system to detect intruders and record intrusion information for monitoring purposes. A sensor module prototype was developed using Arduino Micro Controller, WiFi Shield for Internet connection, PIR motion sensor and a RTC module. Each sensor module was installed and placed at specific areas of the farm with a detection range of about three meters. An intelligent system which detects intruders and records log for the purpose of decision making was achieved. The limitation of the research is that it could only detects intrusion detection but does not specify the type of intruder whether human or animal. Also, the work could cover only a short distance and cannot detect intruders from a long distance.

Mahajan and Mahajan [26] presented IoT Based Agriculture Automation with Intrusion Detection. The objective of the research was to develop an automation system for agriculture using IOT that can control and automate most of the agriculture field a web interface. The automation system consists of a server and several sensors. The server controls and monitors the different sensors and can be easily adaptable. The Arduino serves as the website server and the automation system and be accessed either locally or remotely. A low-cost system that is highly scalable with less modification was achieved. However, the work can only detect motion on the farmland and did not go further determine what exactly is intruding.

Kumar et al. [28] proposed a real time intrusion detection system. The objective of the research was to design and develop a smart intruder detection and alert system which aimed to increase security compared to other commonly deployed electronic security systems. The research employed the use of smart sensors to monitor the presence of intruders near the entry points of the house such as door, windows etc. and raspberry pi was used as the micro controller. A system which sends relevant video data (on detection of an intrusion) to the users and homeowners directly was achieved. However, there is no prompt notification system to inform the farm owners whenever any intrusion occurs.

Roy et al. [27] presented a model for agricultural intrusion detection using wireless sensor network. The objective of the research was to develop a detection system that enables the farmer to receive text messages as well as alarm of an intruder in the farm. The methodology followed a four-layer approach. Layer 1 contains PIR sensors for detecting entrance into the farm. Layer 2 is for processing the data retrieved from the PIR Sensor. Layer 3 does the wireless routing and layer 4 consists of GSM technology for sending text message to the farmer's cell phone, and simultaneously, an alarm is received in the farmer's house. A prototype for intruder detection system that rings alarm in the farmer's house and sends a text message to the farmers phone when an intrusion occurs in the farm was designed. The work only detects motion on the farmland, did not go further determine what exactly is intruding.

Table 2. Farmland Intrusion Detection Systems using Internet of Things (IoT)

Objective	Sensors	Microcontroller	Author	Year
Animal detection	PIR sensor and soil moisture sensor.	Arduino UNO	Mythili *et al.*	2019
Animal Detection	RFID	Raspberry Pi	Santhiya *et al.*	2018
Animal Detection	PIR Sensor	Arduino UNO	Iyapo *et al.*	2018
Animal Detection	Motion Sensor	Arduino Micro Controller	Ajayi and Olaifa	2016
Automation System	Motion Sensor, Light Sensor	Arduino uno Micro controller	Mahajan and Mahajan	2016
Intrusion Detection	Motion Sensors	Raspberry Pi	Kuma *et al.*	2015
Intrusion Detection	PIR and Ultrasonic Sensors	AVR micro-controller	Roy *et al.*	2015

2.3 Farmland Intrusion Detection Systems using IoT with Animal Classification

Ravoor et al. [15] designed a deep learning-based animal intrusion detection system to reduce animal and human conflict by automatically detecting animal intrusions. A prototype of the system is built using Raspberry Pi connected to a laptop computer. Tiny-YOLO and the MobileNetv2-SSD deep learning models are utilized, and the results are compared for animal detection. The deep learning models are pre-trained on MS COCO and Open Images datasets respectively. The prototype is tested using tigers, jaguars and elephants, with detection accuracies of 80%, 89.47% and 92.56% respectively, while operating at 2-3 frames per second. It was noted in the research that animals will often get acclimated to alarm sounds and subsequently ignore them which makes diversion technique incapable.

Schindler and Steinhage [6] worked on Identification of Animals and Recognition of their Actions in Wildlife Videos using Deep Learning Techniques. 8 frames per second video clips are captured by camera traps using infrared cameras and infrared flashlights. The clip taken by camera traps shows four types of animals namely, deer, boars, foxes and hares mostly at nighttime. Each detected animal has a bounding box stating its location, a segmentation mask per animal depicting the exact shape, and a class label depicting the type of animal (here: deer, boar, fox, hare). Mask R-CNN [7] and Flow-Guided Feature Aggregation [8] algorithms were used for animal detection. At the end of the research, a deep learning-based model for the detection and recognition of humans and animals was achieved. The work was limited to few video clips for experimental purposes which resulted in low accuracy.

Shetty et al. [5] developed an algorithm to detect wildlife animals using Convolutional Neural Networks and camera trap images. The image dataset used for the work contains twenty types of animals and one hundred images for every type. The dataset is divided into ten equal parts and the justification for that is to guarantee that results stay unprejudiced to given partitioned data. 90% data is utilized for training and 10% data is utilized for testing. Algorithms used are Support Vector Machine, K-Nearest Neighbor and ensemble classifiers and its variants. An accuracy of 91.4% with weighted K-nearest Neighbor and Deep CNN was obtained which outperforms previous research in anima detection. The work had low accuracy in detecting animals in nighttime images.

Banupriya et al. [14] developed an algorithm to detect wildlife animals and to classify them based on images for easy monitoring and more efficiency. The work considered two types of wild animals to be detected: elephant and cheetah. The dataset was slit into training and testing data in the ratio of 75:25 respectively. CNN was used to develop the detection algorithm. The work did not include sending of notifications to

the forest workers when an animal is detected which served as the limitation.

Mohandass et al. [13] proposed a system for animal intrusion detection to prevent human and wildlife clash and crop protection. Animal intrusion is detected at the boundary of the farm by using sensors such as Passive Infrared sensors, optical sensors and Fiber optic sensors. Arduino Uno serves as the microcontroller and LoRaWAN gateway serves as the gateway and connection is through a wireless medium. The gateway in linked to a cloud server and data can be extracted by the user through a webpage as well as an Android application. At the end of the research, the system detected animal intrusion from video scene and provided the exact location of the area of intrusion which allows for timely action to be taken by the farm owners. The simulation results of image classification based on CNN has a maximum accuracy of 99.34%.

Singh et al. [11] researched on animal intrusion detection using transfer learning together with five high level object detection methods for detecting several types of large animals in real-time video successions captured from at least one monocular camera in moving ground vehicles. A combination of video and static data was used to gather the enormous number of training data needed. Five high level detection models such as Faster Region-based CNN, Region based Fully Convolutional Networks, Single Shot Multibox Detector, RetinaNet and YOLO are used for comparison. The backbone networks used for Faster RCNN are ResNet101, InceptionResnetv2 and NAS; for SSD, Inceptionv2 and Mobilenetv2 are used making a total of 8 object detection algorithms. ResNet101 and ResNet50 are used as backbones for RFCN and RetinaNet respectively. These techniques were chosen because they are proven to have higher detection accuracies. The work provided details about transfer learning acquired by training and testing the models. The research was limited because none of the detectors could provide usable models for deployment.

Sabeenian et al. [12] developed a monitoring and repelling system to safeguard farmlands from wild animals and also to protect them by driving them away automatically without causing loss of human and animal lives. The image dataset used contains about 2500 images and were divided into training and testing data. Three classes of animals namely, elephant, boar and money were considered. The hardware devices used are a personal computer, Jupyter notebook which is used to design the code of the model, surveillance camera and speaker. The surveillance camera is used to record the field area 24/7 which serves as input for the model. The speaker is used to produce audio output which helps to amplify the sound received from the model to the field area to drive away animals. Convolutional Neural Network is used to provide the cognitive skill for classifying the animal detected into a particular class and hence produce the appropriate output. OpenCV and Keras were used as the backend. An accuracy of 70% was achieved. However, the model developed is not cost effective because it requires high memory usage resulting in low speed to train and validate the dataset.

Paramasivam et al. [9] also developed an algorithm suitable for classification and detection of animals from camera pictures of different poses and partial images of animals. Features such as color, gabor and LBP are extracted from the segmented animal images. Classification of animals is done using CNN and symbolic classifiers. The dataset used for training contains 13412 images with 6 classes of animals namely, Spider, Squirrel, Horse, Elephant, Chicken and Butterfly. The captured image is checked for various features of objects that match with features of animals in the training dataset after which detection and classification takes place. The algorithm calculates the accuracy based on the number of matched objects. The accuracy range achieved ranges from 53% to 81%. However, accuracy benchmark set for a detected animal is low which gave room for false detection.

Savagavi et al. [10] worked on animal intrusion detection, recognition and tracking using deep learning methods to minimize human and animal clashes by nonstop and automatic monitoring of areas that are prone to attack. They used a number of network cameras connected to a Passive Infrared Sensor. YOLO algorithm is used as the object detection model. The scope covered Five object classes for the training data which are human, elephant, zebra, giraffe, lion, and cheetah. An accuracy of 98.8% was achieved at the end of the research. However, false alarm occurs when multiple cameras detect the same object class which resulted in multiple notification been generated.

Angadi and Katagall [3] proposed an intrusion detection framework in agribusiness to detect movement in the farm environment, capture the scene data as an image and recognize the object like animal, person or the thing causing motion. The framework was divided into five modules which are Sensor module, deep learning module, PiCam module, e-mail notification module and SMS notification module. OpenCv module installed in Raspberry Pi runs the object detection process and then transfers the result of the detection to the Email notification module. A framework which is used for detecting malicious activities in a farmland was achieved. The limitation was that the research did not consider night view, hence the system cannot run at night.

Vidhya et al. [17] researched on smart crop protection using deep learning approach to protect farmland from animals without hurting the animals or putting human life at stake. Detection is carried out using PIR sensors and Pi camera. Classification is done using Convolutional Neural Network (CNN). The network is trained with a dataset containing many images in each class. The accuracy of each epoch is calculated. A prototype of a smart farm protection system was developed which classifies the animals and can be used to wade them off. However, the system can only detect a range of animals and it cannot detect unauthorized entry of humans which is a major drawback.

Table 3. Farmland Intrusion Detection Systems using Internet of Things (IoT) with Animal Classification

Objective	Sensors	Microcontroller	Author	Year
Animal Detection	Pi Camera	Raspberry Pi	Ravoor *et al.*	2021
Animal Detection	Camera Traps	Raspberry Pi	Shetty *et al.*	2021
Animal Detection	Camera Traps	GeForce RTX 2080 Ti GPU	Schindler and Steinhage	2021
Animal Detection	Video Camera	Raspberry Pi 3	Paramasivam *et al.*	2020
Animal Detection, recognition and tracking	PIR Sensors, Cameras	Raspberry Pi 2	Savagavi *et al.*	2020

Animal Detection	Video Cameras	Raspberry Pi	Singh *et al.*	2020
Animal Detection	Surveillance camera and speaker	Raspberry Pi	Sabeenian *et al.*	2020
Animal Detection	PIR Sensors, Optical Sensors, Fiber optic Sensors	Arduino UNO microcontroller	Mohandass *et al.*	2020
Animal Detection	Camera	Raspberry Pi	Banupriya *et al.*	2020
Animal Detection	PIR Sensor	Raspberry Pi	Vidhya *et al.*	2019
Animal and Person detection	PIR Sensor	Raspberry Pi	Angadi and Katagall	2019

3. CONCLUSION AND FUTURE WORK

The increasing demand of safety and security of human and animals in various fields and environments has brought the challenges of time and computational efficiencies before the researchers working in this area. It is observed that the learning-based approaches are finding more and more attention in recent times due to their performances and availability of computational resources. This paper provides a detailed review of key methods for farmland intruder detection of different authors, and it was discovered that methods that used deep learning algorithms to analyze data collected from IoT sensors had the best performance. This review is also meaningful for developing deep learning algorithms for IoT data analysis which provides valuable insights and guidelines for future progress. Future work should focus on advancing and improving the animal classification process in farmland intrusion detection system.

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